DM2000: A Powerful Tool for Asset Management

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Hainan Fudao Chemical Industry Co. Ltd. (HFCI) is located in Dong Fang, Hainan province, in the southernmost part of China. Construction began in 1994 and the facility was commissioned in 1996. There are two main divisions: an ammonia plant and the first granular urea plant in China. Production capacity is 1000 MTPD (metric tons per day) of ammonia and 1765 MTPD of granular urea. Both products are used as fertilizer.

To reach HFCI from Beijing requires a four-hour flight and then a three-hour drive. Therefore, a modem was installed in the monitoring system to facilitate more efficient

Hainan Fudao Chemical Industry Co. Ltd. in Dong Fang, Hainan, China.

Plant	Train	Purpose	Speed (rpm)	Power (kW)	Bearing Types		Driver type
					Radial	Thrust	
Ammonia	Natural gas compressor	supply compressed natural gas to reformer	10,480	3,142	5-shoe, tilting-pad	Kingsbury	Steam turbine
	Process air compressor	supply compressed process air and plant air	7,400	8,490	5-shoe, tilting-pad	Kingsbury	Gas turbine
	Synthesized gas/ recycled gas compressor	supply compressed process gas to synthesis section	11,260	7,821	5-shoe, tilting-pad	Kingsbury	Steam turbine
	Refrigerated ammonia compressor	compress ammonia gas for refrigeration	9,540	5,395	5-shoe, tilting-pad	Kingsbury	Steam turbine
Urea	Carbon dioxide compressor	supply the pressurized CO_2 to the urea converter	8,407 (LP shaft) 12,165 (HP shaft)	7,460	5-shoe, tilting-pad	Kingsbury, (except gearbox where Michell-type is used)	Steam turbine

Table 1 – Machine train summary.

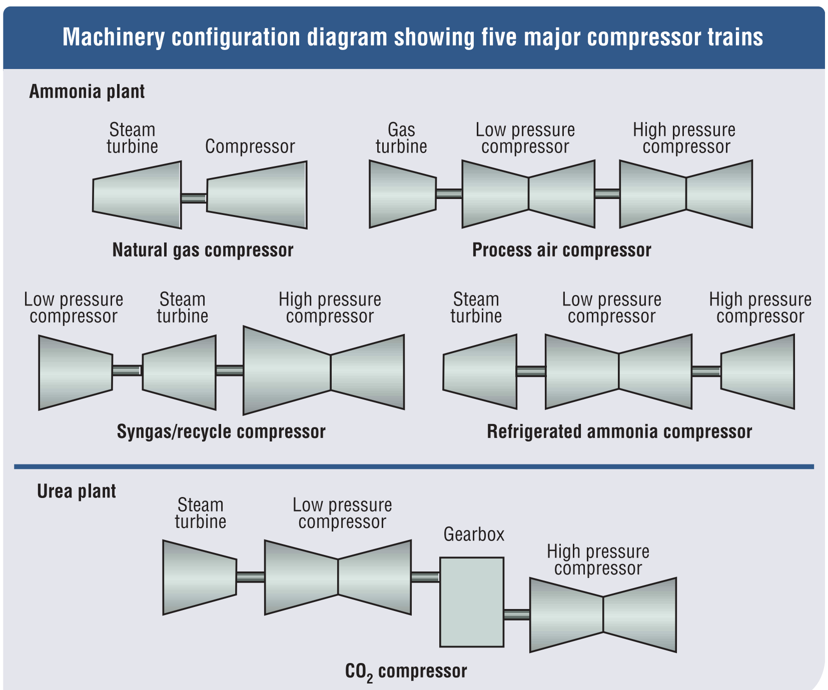

Figure 1.

technical support via Remote Access Service (RAS) from Bently Nevada's Beijing office. This saves both time and money when diagnosing a problem at the plant.

Production Process

There are five major machine trains involved in production: the natural gas compressor, the process air compressor, the synthesized gas/recycled gas compressor, the refrigerated ammonia compressor, and the carbon dioxide compressor. These are summarized in Figure 1 and Table 1.

Figure 2 outlines the fertilizer production process. ICI AM, UK, developed the ammonia process and the urea process was co-developed by Snamprogetti, Italy, and Hydro Fluid Granulation, Norway.

Installed Machinery Protection and Management System

HFCI uses Bently Nevada's 3300 Series machinery protection systems to monitor all five critical trains. In the initial installation, only the carbon dioxide and ammonia trains were connected to Bently Nevada's condition monitoring software, Data Manager® 2000 (DM2000). In 1999, the remaining three machine trains were connected to the DM2000 system (Figure 3). As mentioned previously, a modem connection facilitates remote access to the system, allowing easier support by Bently Nevada without the need for 16 hours of round-trip

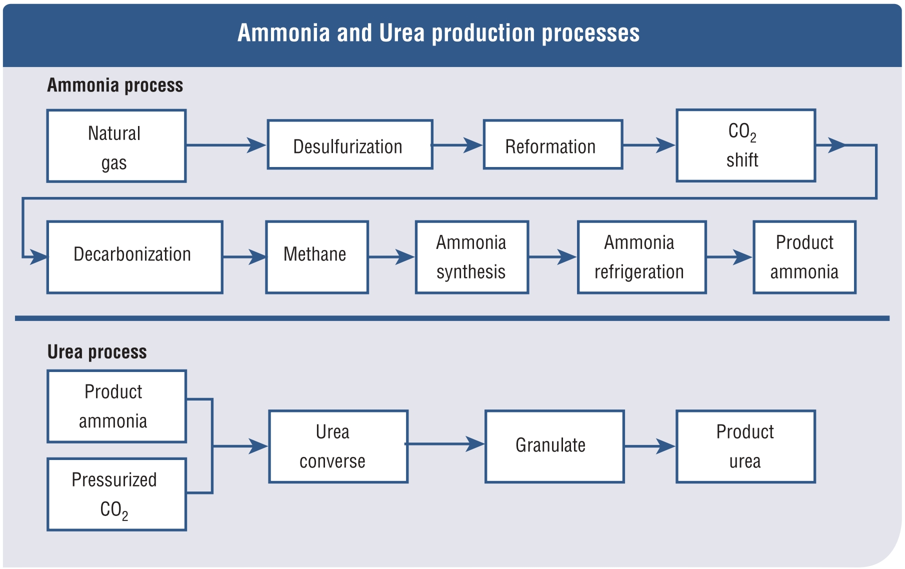

Figure 2.

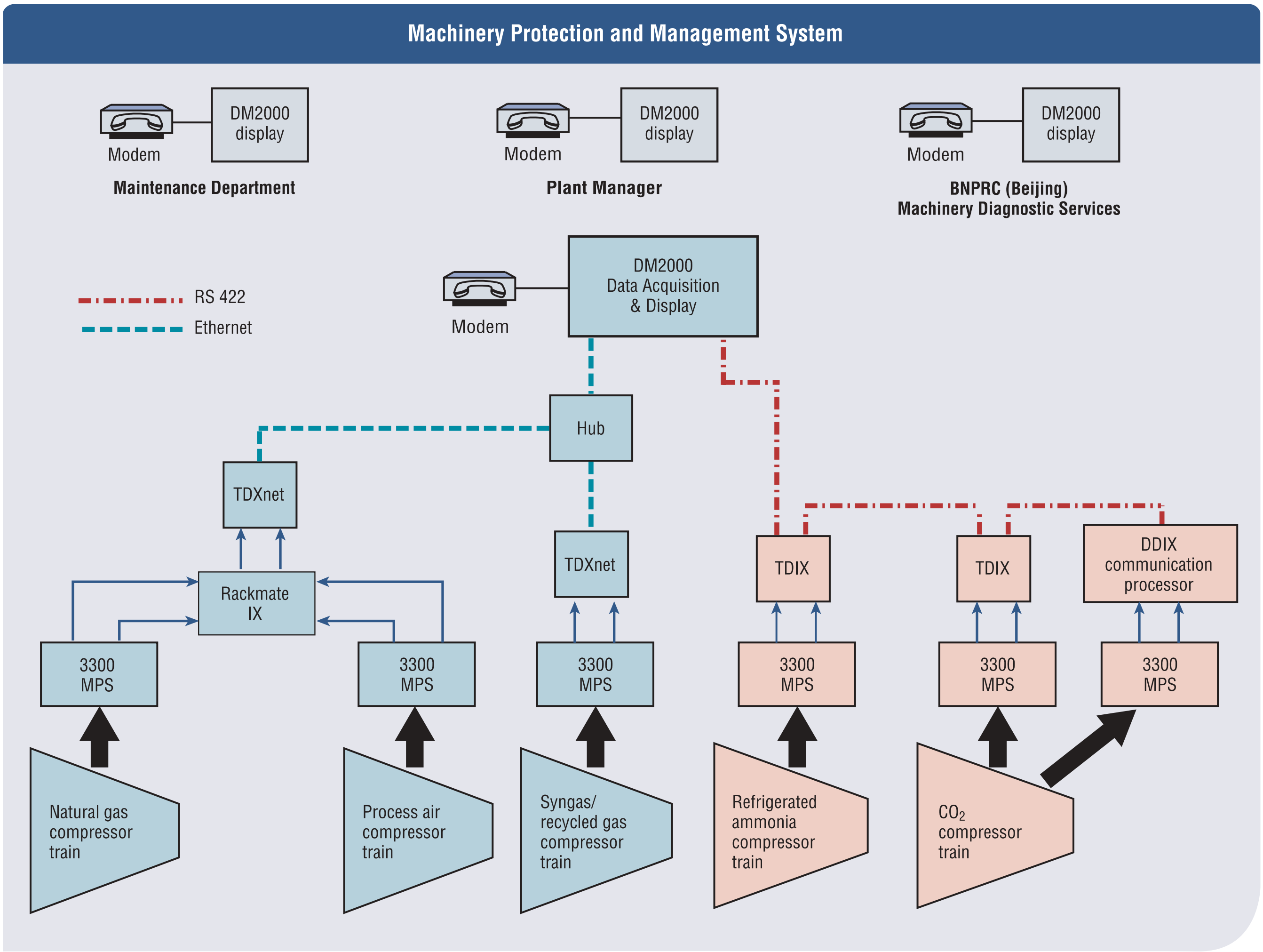

Figure 3.

travel. Since the system was installed, the DM2000 has provided extremely valuable data for HFCI's maintenance department. The remainder of this article focuses on three case histories that illustrate the value of the system.

DM2000 Plots Identify Problems

Case #1. Thrust Bearing Damage in Ammonia Refrigeration Train

This machine train consists of a Mitsubishi steam turbine and a Hitachi compressor. Bearing types are as noted in Table 1.

Event

In March 2000, the ammonia unit was tripped by excessive thrust position on the steam turbine. Ten minutes later the operator tried to restart the unit but failed due to excessive thrust position again. DM2000 automatically collected the data during alarm and shutdown conditions, as well as from the period leading up to the alarm. Baseline data was collected when the machine train was under normal operation. This information proved to be very useful in identifying the source of the problem.

Diagnosis

First, trend data for the steam turbine thrust position was checked. As shown in Figure 4, gap voltage fluctuated from –11.1 Vdc to –19.6 Vdc and came back to –14.4 Vdc within 13 seconds. This was indeed highly irregular and indicative of a problem. Dynamic data from the axial probes was also illuminating, as is shown in the half spectrum cascade plot of Figure 5. This revealed the presence of an unusual subsynchronous component (well below 0.5X), and further confirmed that something was wrong in the rotor's axial direction. Other DM2000 data was reviewed as well, but the radial vibration at each bearing did not change much compared to the baseline data. There was no indication, for example, of a radial rub or other anomaly. It was concluded that thrust bearing damage had probably occurred and plans

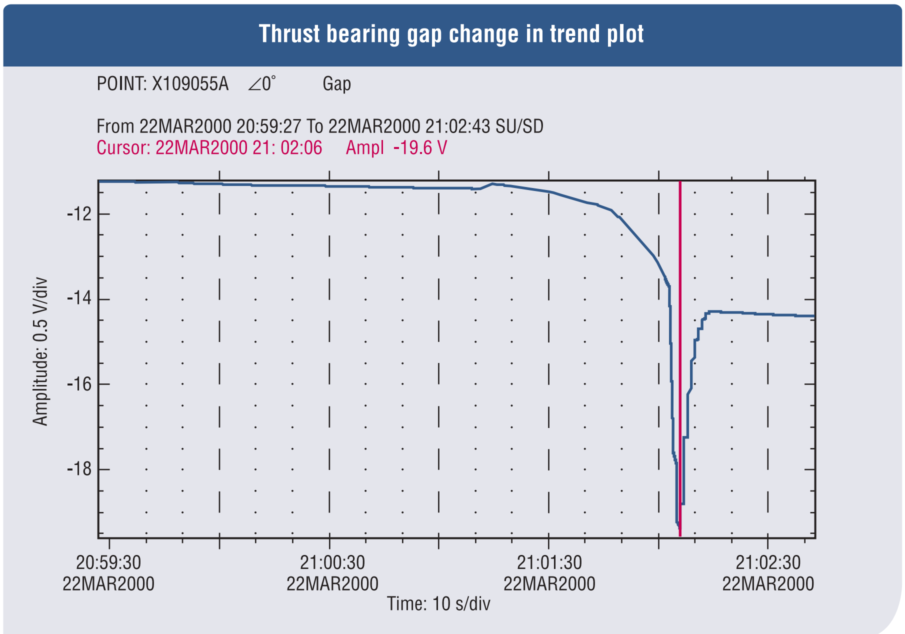

Figure 4.

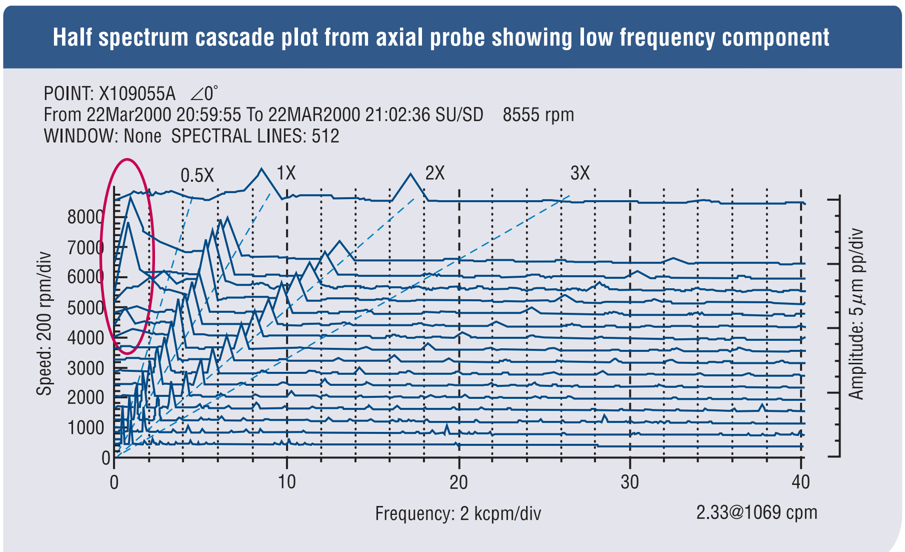

Figure 5.

Case History #1 - Refrigeration ammonia compressor.

were made for Maintenance to replace the thrust bearing only. When the bearing was opened up, suspicions were confirmed: the Babbitt metal was severely damaged. After thrust bearing change out, start up was smooth and the machine operated without further problems.

Root Cause

While the ability to isolate the problem to the thrust bearing was valuable, it still did not answer the question "why did excessive thrust bearing wear occur in the first place?" By analyzing the process operation, it was found that the boiler did not work properly and the steam drum level exceeded the permitted value. As a result, wet steam had entered the turbine and caused a heavy disturbance force in the axial direction. Fortunately, damage from this excessive loading was limited to the thrust bearing and did not extend to seal damage or axial rubs between blading and casing.

Savings

Normally a failure of this nature would require removal of the entire machine case and three days of downtime to determine whether the excessive axial movement resulted in axial rubs. In this case, the DM2000 data indicated no problems other than the thrust bearing itself, and repairs and inspection were limited to this bearing. *Savings were estimated to be at least 720,000 USD – twelve times the initial cost of the machinery protection and management system.*

Case #2. Startup Procedures for CO_2 Unit

The CO_2 compressor unit, manufactured by Nuovo Pignone, is composed of a high pressure and a low pressure (HP and LP) compressor, driven by a steam turbine.

Event

On 5 January 2000, the CO_2 unit was tripped when another part of the process was brought down. Shutdown data analysis did not identify anything abnormal. The following morning, a fully automated restart was attempted using the Digital Electric-Hydraulic (DEH) unit control system. During start up the steam turbine tripped at 2905 rpm due to high vibration. Operations had witnessed the

Full spectrum cascade showing dominance of synchronous (1X) vibration frequency

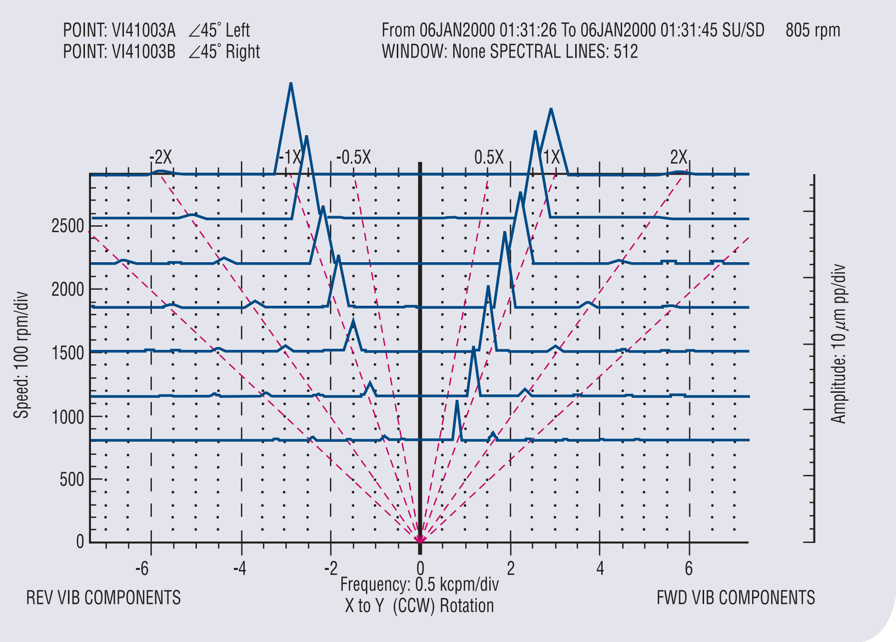

Figure 6.

Bode plots showing aborted startup data compared with baseline data

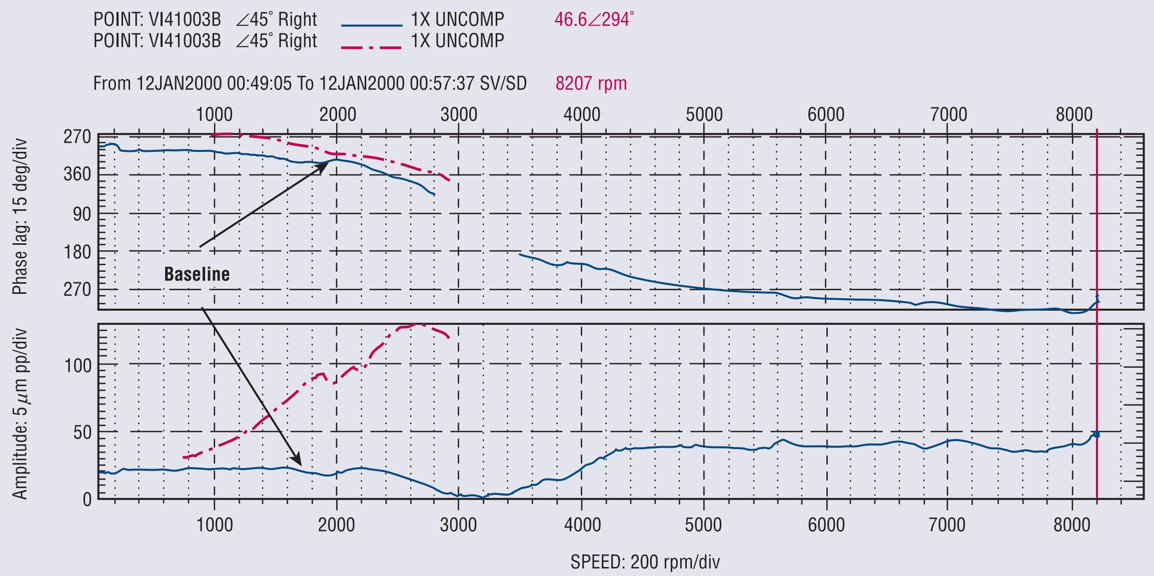

Figure 7.

Bode plots showing data from 920 rpm to 5000 rpm

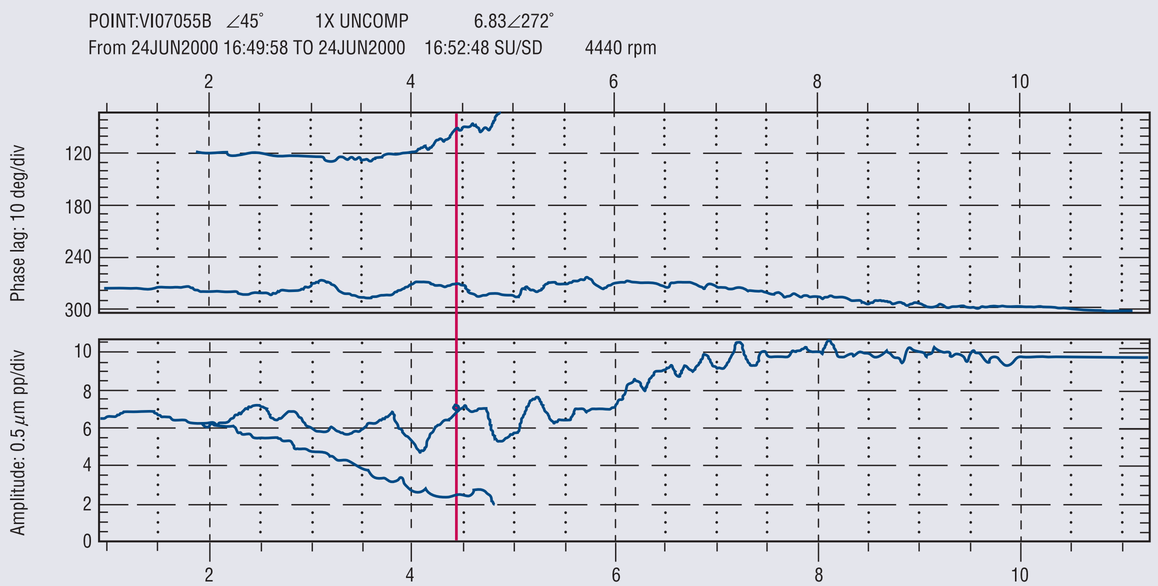

Figure 8.

same occurrence (trip during startup due to high radial vibration) several times before. However, there was previously no means to determine the root cause, since the DM2000 system had not yet been installed on this train.

Diagnosis

First, the transient data was reviewed for the steam turbine. Using a full spectrum cascade plot (Figure 6), the major frequency component was synchronous with rotating speed (1X).

A Bode plot (Figure 7) was then analyzed. It showed a distinct difference from normal startup behavior, as noted by comparing the baseline data in Figure 7 with the data collected during the aborted startup. A change in balance seemed unlikely, and the immediate suspicion was thermal bow.

Case History #2 - CO_2 compressor.

Root Cause

It was suspected that the shaft bow resulted from an inadequate startup procedure that did not allow the rotor to warm up and expand properly. A unit restart, using a manually controlled procedure, maintained 1000 rpm for 15 minutes and allowed the rotor to fully warm up and expand. Automated control via the DEH system was resumed and the rotor was ramped up to operating speed. The entire startup was monitored closely, viewing appropriate DM2000 data. Smooth operation was observed throughout and vibration amplitudes were less than 50 μm. This modified startup procedure was determined to be feasible and effective for the CO_2 unit and has been permanently implemented.

Savings

Although the cost of aborted startups has not been rigorously calculated, downtime caused by multiple startup attempts is costly, and each startup represents machine wear and tear. In this case, the solution was simple: allow the rotor to warm up at 1000 rpm for an extra 15 minutes prior to full-speed ramp up. It is also worth noting that a bowed shaft, which is easily fixed, can sometimes result in a bent shaft if the unit is not tripped. A bent shaft represents an extremely costly event with significant repairs and downtime required.

Case #3. Valve Problem in Synthesized Gas / Recycled Gas Compressor Unit

The synthesized gas / recycled gas unit consists of two Hitachi compressors and a Mitsubishi steam turbine. As with other units, the compressors were equipped with traditional double-acting Kingsbury-type thrust bearings and five-shoe tilting-pad radial bearings.

Event

During a regularly scheduled shutdown on 24 June 2000, the rotor speed suddenly (within 7 seconds) increased to nearly 5000 rpm after having coasted down to 920 rpm. Operations personnel were not able to explain this. The main valve had already been closed and the control system displays did not provide any information.

Diagnosis

Because both process and vibration data had been integrated into the DM2000 system, data plots clearly displayed information relating the exhaust valves to the relevant vibration behavior. In Bode plots (Figure 8),

Case History #3 - Synthesized gas/recycled gas compressor.

different vibration amplitude and phase was noted from 920 rpm through 4850 rpm than was typical of a startup through the same speed region. A full spectrum waterfall plot (Figure 9) was also examined and revealed a significant reverse precession component, far bigger than the forward component. At this point, it was thought that rubbing may have occurred. However, upon further investigation, the shaft centerline position plot (Figure 10) indicated that reverse rotation rather than reverse vibration had actually occurred. This is illustrated in Figure 11. Please note that the radial bearing used in this machine was a five-shoe, tilting-pad design.

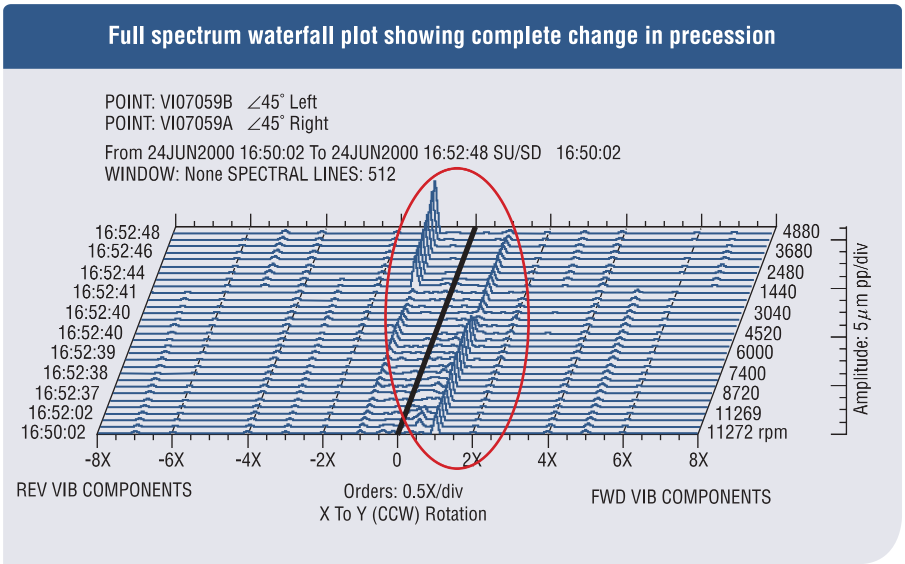

Figure 9.

For a Load-on-Pad (LOP) configuration of tilting-pad bearings, the shaft supporting oil wedge is established and position is maintained on the bottom pad. Due to the location of the wedge, the shaft rises essentially straight up into normal running position, although there is a slight offset from the true vertical centerline. Usually, the offset is in the direction of rotation as shown in Figure 11. In general, for a specific bearing, the centerline position will retrace the same pattern each time the machine is started or stopped. Figure 10 shows that as the machine coasted down from 11,269 rpm, the shaft centerline followed a predictable path from slightly right of center toward the bottom of the bearing clearance. This would be predicted from Figure 11. However, when the machine suddenly accelerated from 920 rpm to 4880 rpm it did not retrace the same path of upward and to the right. Instead, it traveled down through the vertical centerline of the bearing clearance and then upwards and to the *left* – the exact opposite direction one would expect. The combination of reverse precession seen in the full spectrum plot and the data from the shaft

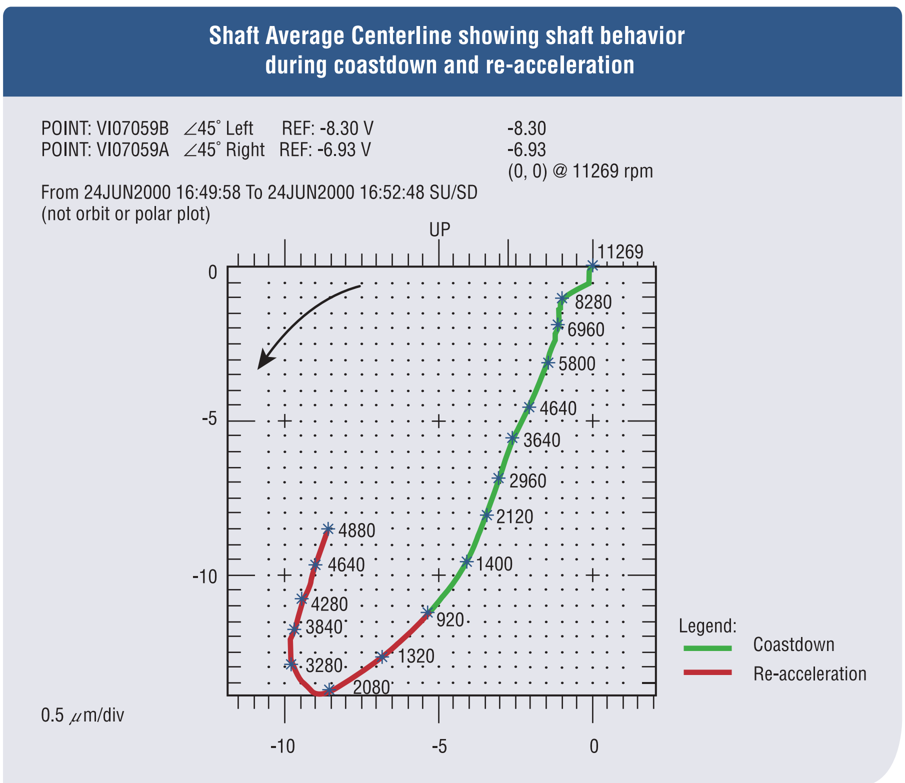

Figure 10.

Typical shaft centerline position behavior for tilting-pad bearing

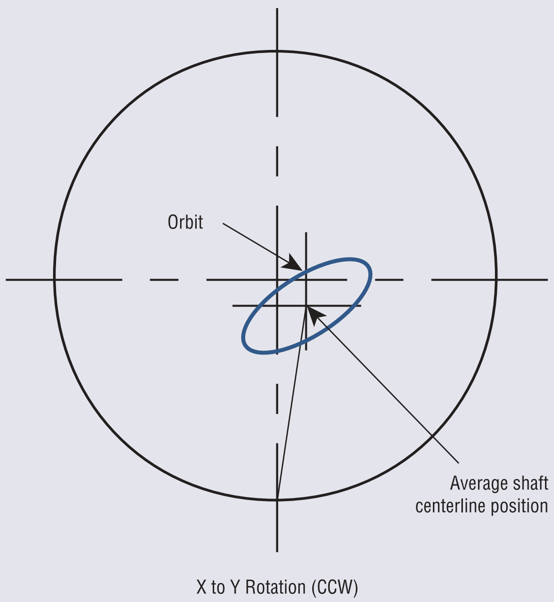

Figure 11.

centerline plot strongly suggested a reverse rotation event had occurred.

Root Cause

Reverse rotation generally occurs because either liquid or gas is allowed to flow into the machine in a direction opposite its normal flow. In this case, it was assumed that reverse rotation had resulted due to process gas return into the compressor. Faulty check and cut-off valves were suspected and confirmed and appropriate maintenance on the valves was performed.

Conclusion

The case histories described in this article are just three of numerous situations where better machinery information has helped HFCI save money on maintenance and reduce downtime. Their use of remote access allows Bently Nevada's Beijing office to provide supplemental support quickly and without travel-associated costs. While the system has gained the support of maintenance personnel, it has also proven it's worth as a source of information for operations personnel as well, allowing them to troubleshoot and adjust processes and procedures for better plant and machinery availability.